Laboratories

Inspiring Students and Engaging Industry with Green Chemistry

Summary: As an undergraduate student at the University of Massachusetts Boston, John Warner was an aspiring musician until he was inspired by a course in chemistry. After receiving his Ph.D. in medicinal chemistry from Princeton University and working in industry as a developmental chemist, Warner returned, twenty years later, to his undergraduate institution to pursue research and develop the first Green Chemistry Ph.D. program in the world. Researchers and students in the program take their "bioinspiration" by understanding how chemistry works in nature, and applying these principles to real world, relevant problems. While the green chemistry approach is revolutionary, the program results are truly extraordinary. UMass Boston has experienced an increased enrollment in undergraduate chemistry; received significant research funding for the green chemistry program areas; found itself flush with highly qualified applicants for the Ph.D. program, and seen its chemistry program graduates sought by employers.

Project Goals

1. Develop a Green Chemistry Graduate Program.
2. Obtain a steady source of funding and students for the program.
3. Provide graduates with the tools and experience to design materials and processes with minimal or reduced environmental or toxicological impact.

Description

- Undergraduates were unable to relate chemistry to their lives, or the products they used.
- Many chemistry graduates were unprepared for jobs in industry where multidisciplinary perspectives are valued and methods to minimize hazardous materials, inefficiency and waste are sought.
- Environmental, health and safety issues associated with chemical research were not fully evaluated.
- Current pollution prevention and micro-scale teaching methods did not go far enough in changing the way in which chemists design experiments and create new products.

Campus Profile

University of Massachusetts Boston
Boston, MA
FT Students: 13,300
FT Faculty: 818
Undergraduate majors: 73
Master's degree programs and tracks: 40
Graduate certificate programs: 24
Doctoral programs and tracks: 14
Campus Operating Budget: $176 million for FY '03
# of Buildings: 6
Campus Area: 175 acres

Green Activities

UMB has been an active participant in the EPA sponsored Project XL for New England Academic Laboratories to pilot an alternative system for managing hazardous wastes in laboratories.

John Warner has received numerous Chemistry awards.

Pre-Project Considerations

1. Understand the real world application of chemistry. Warner has both the academic pedigree and the industrial experience, as a former senior researcher at Polaroid, to assist students in understanding how chemistry is applied by industry and gain the requisite skills.
2. Develop skills at communicating "green" chemistry principles to government, business, funding and academic communities and distinguishing these innovative life cycle approach from other current practices. For example, micro-scale techniques may continue to use the same methodology (but with smaller quantities of chemicals) and certain pollution prevention techniques may be applied only to a portion of an experimental methodology.
3. Think about green chemistry as a framework to bring together multiple departments, disciplines, or faculty members.

> Green Chemistry is the utilization of a set of principles that reduces or eliminates the use or generation of hazardous substances in the design, manufacture, and application of chemical products.

Steps Taken

Principles of Green Chemistry

The following " 12 Principles of Green Chemistry*" are reprinted here from the UMB web site at http://www.greenchemistry.umb.edu/html/understand/primciples.htm

1. **Prevention** – It is better to prevent waste than to treat or clean up waste after it has been created.
2. **Atom Economy** – Synthetic methods should be designed to maximize the incorporation of all materials used in the process into the final product.
3. **Less Hazardous Chemical Synthesis** – Wherever practicable, synthetic methods should be designed to use and generate substances that possess little or no toxicity to human health and the environment.
4. **Designing Safer Chemicals** – Chemical products should be designed to affect their desired function while minimizing their toxicity.
5. **Safer Solvents and Auxiliaries** – The use of auxiliary substances e.g., solvents, separation agents, etc. should be made unnecessary wherever possible and innocuous when used.
6. **Design for energy efficiency** – Energy requirements for chemical processes should be recognized for their environmental and economic impacts and should be minimized. If possible, synthetic methods should be conducted at ambient temperature and pressure.
7. **Use of Renewable Feedstocks** – A raw material or feedstock should be renewable rather than depleting, whenever technically and economically practicable.
8. **Reduce derivatives** – Unnecessary derivatization, use of blocking groups, and temporary modification of physical/chemical processes should be minimized or avoided, if possible, because such steps require additional reagents and can generate waste.
9. **Catalysis** – Catalytic reagents are often superior to stoichiometric reagents.
10. **Design for Degradation** – Chemical products should be designed so that at the end of their function they break down into innocuous degradation products and do not persist in the environment.

> **A Green Chemistry Workshop**
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> "Chemists entering the world of industry, particularly the pharmaceutical industry, often find they are not prepared for many of the challenges associated with the design and application of chemical technology within a commercial R&D setting. There are complex issues of safety, scale-up, engineering, regulatory constraints, timelines and economics to be dealt with… we believe that the knowledge and application of green chemistry principles will become more essential within R&D in order to achieve economic and environmental sustainability."
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> (from a Green Chemistry Workshop for undergraduates sponsored by the world's largest pharmaceutical company.)

11. **Real-time analysis for Pollution Prevention** – Analytical methodologies need to be further developed to allow for real-time, in-process monitoring and control prior to the formation of hazardous substances.
12. **Inherently Safe Chemistry for Accident Prevention** – Substances and the form of a substance used in a chemical process should be chosen to minimize the potential for chemical accidents, including releases, explosions and fire.

Formed the Center for Green Chemistry

Dr. Warner took the following actions in the formation of the Green Chemistry Program.

1. Developed a Ph.D. Program in Green Chemistry at UMass Boston.
2. Traveled widely to speak at conferences, workshops and industrial meetings on the concepts of green chemistry and current research being conducted at the Center for Green Chemistry.
3. Designed and built a state-of-the-art laboratory.
4. Became chair of the Chemistry Department.
5. Has continued to promote green chemistry and work with academic, government and industrial partners.

Green Chemistry draws its inspiration from nature's operations at the molecular level.

It takes a life cycle approach to the design of chemical products and processes by asking students to think about which chemicals to use in the design, what byproducts are generated, how much energy is used, and what wastes will be generated in the lab, during each stage of a product's useful life.

Participants

The Green Chemistry Program is a multidisciplinary program. It is physically located in the Chemistry Department, where Dr. Warner serves as chairperson The research group includes students and faculty from Chemistry, Biology, Biochemistry, Psychology, Computer Sciences, and Environmental, Coastal and Oceanographic Studies (ECOS). The research group meets weekly to discuss the status of research, grant proposals, and share material.

All student researchers in the group are required to participate in community outreach initiatives. Student researchers go to K-12 classrooms to describe their research or student and community groups come to the laboratory for hands-on presentations. This requirement for students in the green chemistry research program reflects Warner's belief that chemistry research and principles must be accessible to, and understood by, people of all walks of life.

Performance and Benefits

Green Chemistry Laboratory for Education and Research

The 2000 square-foot laboratory for the Center for Green Chemistry was designed to meet the specific needs of the researchers and to be consistent with the laboratory's mission. The laboratory, built in 1999, included the following flexible and adaptable design features:

- Most hoods were designed for work with relatively benign chemicals that can be contained under transparent portable hoods. These hoods were linked by quick connect fittings to flexible trunk exhaust ducts leading to ceiling exhaust ports, which also provide general exhaust.
- Traditional fume hoods were located at each end of the laboratory for work with more hazardous materials.
- Two-thirds of the laboratory was designed as flexible research space. The lab tables could be reconfigured in many different positions around a grid of 36" high fixed service pedestals that carry gas, water, power and data.
- Variable airflow hoods were used to limit exhaust requirements. The fume hoods shared capacity with trunk systems. The dual exhaust system allowed researchers to choose which system to activate, depending on needs. Individual task boxes allowed different types of capture: bottom slot, face velocity control and hood, for example.

Green Chemistry Research

Research projects within the Group aim to solve real world problems, while applying the principles of green chemistry. Warner's research focuses on molecular recognition and self-assembly, which serves as a unifying theme for a number of different research areas being pursued by the Group. The Green Chemistry Program has been successful in obtaining research funds from grantors and has conducted research in the following areas:

- Solar energy devices
- Non-linear optical materials
- Sensor and detectors
- Thin film coating technologies
- Biodegradable polymers
- Non-covalent derivatization
- Controlled drug delivery systems
- Ultraviolet monitoring devices
- Methods for synthesizing medicinal products

Lessons Learned

1. Students will enroll in chemistry classes and graduate programs if chemistry education is interesting and perceived as relevant.
2. Granting organizations will support green chemistry research projects.
3. Industry will support programs that provide chemistry majors and graduate students with principles, tools and techniques that can be applied to improving products, saving money and eliminating waste.
4. Don't be held back. Pursue your academic goals and your environmental values.

Further Information and Resources

Dr. John Warner, john.warner@umb.edu or (617) 287-6165
Other members of the Warner Group http://www.greenchemistry.umb.edu/html/warnerGroup/people.htm

Other Green Chemistry Programs or Resources

University of Oregon http://www.uoregon.edu/~hutchlab/greenchem/atoregon.html
EPA Green Chemistry http://www.epa.gov/greenchemistry/

A new Memorandum of Understanding governing the establishment of the New England Green Chemistry Consortium has been signed by the six land grant universities in New England: the University of Massachusetts, University of Connecticut, University of Maine, University of New Hampshire, University of Rhode Island, and University of Vermont. The New England Green Chemistry Consortium (NEGCC), which will be organized in Massachusetts and have its principal office, initially, at NETI at the University of Massachusetts Amherst, will primarily serve to build strategic partnerships/alliances in green chemistry in the New England area among the six land-grant universities, small and large businesses, and state and federal governments.

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Green Chemistry, subdivision within the American Chemical Society
http://www.chemistry.org/portal/Chemistry?PID=acsdisplay.html&DOC=education\greenchem\index.html
Green Chemistry Network in the UK http://www.chemsoc.org/networks/gcn/about.htm

Greening Across the Chemistry Curriculum, University of Scranton,
http://academic.scranton.edu/faculty/CANNM1/dreyfusmodules.html